Overholser & Shirley

A compressed air switch

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A COMPRESSED AIR SWITCH

BY

MARTIN JACOB OVERHOLSER

AND

ORIN EARL SHIRLEY

THESIS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

MARTIN JACOB OVERHOLSER and ORIN EARL SHIRLEY

ENTITLED A COMPRESS AIR SWITCH

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Electrical Engineering

J M Bryant
Instructor in Charge

APPROVED: Ernst Berg

HEAD OF DEPARTMENT OF ELECTRICAL ENGINEERING

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A COMPRESSED AIR SWITCH.

INTRODUCTION.

The energy stored in an electric circuit has given rise to considerable trouble on breaking it, especially, in large power circuits. When the circuit is broken this energy has to be dissipated in the arc that is formed. If a current of I amperes is broken in a circuit of inductance L, the stored energy is represented by $\frac{1}{2}LI^2$. When a circuit of capacity C and with an electromotive force E impressed upon it is broken, the stored energy is equal to $\frac{1}{2}CE^2$. The energy of all the moving parts of the apparatus connected with the circuit must be dissipated in case of short circuit.

With the advent of high voltages and currents, the air break switch was devised to open the circuit. This however gave a bad arc, which often set fire to surrounding inflamable objects. The heat of the arc caused the copper to burn at the points of contact, which decreased the current carrying capacity of the switch and in a short time this made necessary a new switch. Somewhat later it was found that oil had certain properties, which kept the copper quite cool, and at the same time extinguished the arc very quickly. Hence the oil switch was devised to meet the difficulties which confronted the air break switch. The oil switch also had the valuable qualification that it broke the circuit at the zero point in the current wave.

The power in electric circuits, however, has increased very rapidly. With very severe arcs gases were formed in the oil. These gases expanded and caused the oil to be thrown out of the openings in the casing, or if there were no openings the casing might be blown to pieces. The ordinary single cell oil switches were not used to break power exceeding 5900 kilowatts. No oil switch was warranted to break power of more than 40000 kilowatts. These sizes, however, were sufficient until quite recently, but in some stations this safe allowable load for the switch has been exceeded. In this case the power is sectionalized, that is, divided up so that no one feeder in a generating station may carry over 40000 kilowatts.

The object of this thesis was to investigate this problem along another line, which was that of operating a switch in compressed air. The apparatus for carrying on the tests was designed and constructed by the authors of this thesis. Very little experimenting was done with this method, but there has been enough to warrant a future investigation of the subject. The power obtainable was comparatively small, but it served to show the general principles governing the operation.

DESCRIPTION OF APPARATUS.

SWITCHING COMPARTMENT.

The greatest difficulty in the design of the apparatus for this switch, was to secure a switching compartment as nearly air tight as possible, and at the same time to have the switch operate without getting out of order, since every time it failed to operate, it must be taken apart, and this would give an additional chance for leakage. The assembled view of the switch and outside casing is shown in plate I, which is a vertical cross section. The casing which was used to enclose the switch and hold the compressed air, consisted of a wrought iron pipe and a cast iron T. The pipe was four inches in diameter and thirteen and one-fourth inches in length. The wrought iron pipe is represented by a in Plate I, and the T by b in Plate I. The two ends of the pipe were threaded externally, and the openings in the T were threaded internally. The pipe was screwed into one of the openings of the T and a four inch cap was screwed on the other end of the pipe. This cap is represented by c in Plate I. A cast iron plug, indicated by d Plate I, was screwed into the lower opening of the T. A wrought iron nipple was screwed into the side opening of the T and the cap was screwed on the nipple. The nipple is shown by O in Plate II. An inch and a quarter hole was drilled in the center of this cap. A piece of quarter inch plate glass three

and one-half inches in diameter was placed over this hole, to provide a means of watching the arc. Rubber gaskets, indicated by 1-1 in Plate II, were placed on both sides of the plate glass, and an iron ring, shown by 3 Plate II, was placed on the inside of ~~inside of~~ the inner rubber gasket. The end of the nipple acts as a shoulder for the plate glass. When the cap was screwed on the nipple, it forced the plate glass and iron ring against the end of the nipple. The rubber gaskets were used to take up the strain in the glass, and to make the joint air tight. The iron ring protected the gasket from being cut by the sharp edge of the nipple.

UPPER AND LOWER CONTACTS.

The current conducting device consisted of an upper and lower contact. The lower contact was attached to the plug in the bottom of the T, and the upper contact consisted of a short brass quarter inch rod attached to a movable steel rod. This brass tip was arranged so that it could be forced into a hole in the lower contact. The lower contact is represented by f in Plate I, and the brass tip by 9 in Plate II. The lower contact consisted of a short piece of brass passing through the plug in the bottom of the T and insulated there-from by a hard rubber bushing and washer. It was held in place by a shoulder on the inner side and a nut on the outside. One terminal of the switch was connected to the lower contact and the other to the outside casing.

GUIDES FOR THE UPPER CONTACT.

In order that the upper contact should fit exactly into the hole in the lower contact, it was necessary that the rod holding the upper contact should move in the same staight line. The guides used for this purpose were a bolt, represented by 10 in Plate II, and a brace, indicated by 11 in Plate II. The bolt was five-eighths inch in diameter and six inches long, with a three-eighths inch hole drilled so that it came exactly in the center of the pipe. Rubber gaskets were placed under the head and nut to make the joint air tight. The brace consisted of a flat steel plate, supported by two steel rods, which were fastened to the cap at the top of the switch. Round steel nuts were screwed upon these rods to serve as shoulders on the lower side of the pipe cap. Rubber gaskets were placed under the nuts on the outside of the pipe cap. A hole was drilled in the steel plate in line with the hole in the lower contact and the one in the bolt.

TRIPPING MECHANISM.

A mechanical means was devised for opening the switch. The details of this apparatus is shown by the photograph on page 21. A thin flat steel plate was attached to the rods holding the upper guide for the sliding rod holding the upper contact. A rectangular slot was cut out of this piece and a sliding trigger placed in the slot. This trigger is represented by 12 in Plate II.

MECHANISM TO REGULATE LENGTH OF ARC.

The length of the arc was regulated by means of a devise on the top of the cap, as shown at 13 in Plate II. A steel plate, similar to the upper guide was fastened to the top of the pipe cap by means of two rods about five inches long. A three-eighths inch hole was drilled in line with the holes through which the sliding rod passed. A rod was placed in this hole and graduated so that it read the gap between the upper and lower contact when the switch was open. The rod was held in place by means of a set screw. When the switch was tripped, the tripping rod 14 in Plate II, was forced up against the graduated rod.

OTHER FEATURES.

The base of the switch was made of a block consisting of four layers of one inch pine lumber twelve inches in width, and about eighteen inches in length. A hole was cut near the center of the block to admit the lower contact of the switch.

The compressed air was admitted to the switch through a half inch pipe. A gauge was placed in this pipe to read the pressure. A baffle plate was placed near the opening to admit the air so that the air currents would not affect the arc.

METHOD OF TESTING.

The testing was started by putting 110 volts direct current across the reactance coil of a constant current transformer with the switch in the circuit. The switch was opened and closed under different air pressures, but no data was taken, as this was merely to get some idea as to how the switch would operate. The same tests were performed using 220 volts direct current.

TEST A.

The field of two five kilowatt 125 volt Edison bipolar machines were connected in parallel and used as a reactance coil. The switch was placed in the circuit and 220 volts impressed across the coils. Direct current was used in this test. Starting at atmospheric pressure, readings were taken of voltage, current, gauge pressure, and the length of gap at which the arc would hold for approximately three seconds. The time entered as a personal equation. The pressure was varied from atmospheric up to about thirty seven pounds per square inch gauge, taking intervals of five pounds per square inch. The above set of readings were taken for each pressure. The power was obtained from the University Power Plant.

TEST B.

The field coils of one of the Edison bipolar machines were used in this test and 220 volts direct current impressed across them. The same operations were per-

formed as for test A.

TEST C.

The field coil of a three kilowatt 500 volt Edison bipolar machine was connected in circuit in series with the switch and 450 volts impressed across them. The power was taken from the direct current side of a double current generator driven by a direct current motor. The same data was taken as for test A.

TEST D.

The same coils were used as for test A and 110 volts direct current impressed across them. The same data as in the previous test was taken.

TEST E.

A seven and one-half kilowatt inductor alternator was brought to full voltage of 220 volts and short circuited through the switch. The switch was immediately opened and the arc observed. The same range of pressure was used as for the previous test, but no data was taken since there was no noticeable difference in the appearance of the arc through the range of pressures available at the time of the test.

DISCUSSION OF DATA AND CONCLUSIONS.

The results obtained from the various tests, which were performed with direct current, can be best seen from the curves. The curves are plotted between the air gaps in inches and the absolute pressures in pounds per square inch, using the pressures as abscissae. Each one of the curves is a straight line with a negative slope, which shows that the air gap varies inversely as the first power of the absolute pressure. However, the slopes of the straight lines vary considerable.

The tests with the seven and one-half kilowatts inductor alternator do not show any noticeable variation in the arc throughout the range of pressure. The intensity of the arc depended upon the instantaneous value of the current at the time when the circuit was broken.

The oscillogram does not show a very great rise of voltage when the circuit is broken. This is probably due to the fact that the inductance and the current were not very large. The curve shows that when the switch was first opened the voltage rose very irregularly for a short time, after which it suddenly rose to the maximum value. The part of the curve which shows the decrease in voltage falls quite gradually in a smooth line, similar in form to the exponential curve. The irregular rise in voltage when the switch was first opened was due to the drop across the flaming arc. The arc fluctuated considerably, increasing and then decreasing in size, until it was fin-

ally extinguished. The sudden rise of voltage occurred when the arc broke.

TEST A

Time of arc approximately three seconds.

Voltage in circuit.	Current amperes	Pressure gage lb./sq.in.	Pressure absolute lb/sq.in.	Length of arc inches.
218	5.9	0	14.7	$2\frac{1}{4}$
220	5.7	4.9	19.6	$2\frac{1}{16}$
222	6.0	10.5	25.2	$1\frac{13}{16}$
222	6.0	15.1	29.8	$1\frac{5}{8}$
220	5.9	20.9	35.6	$1\frac{1}{2}$
218	5.9	25.0	39.7	$1\frac{3}{8}$
222	6.0	32.5	47.2	$1\frac{1}{8}$
214	5.8	36.5	51.2	$\frac{13}{16}$
226	6.1	30.0	44.7	$1\frac{1}{16}$
221	5.95	25.0	39.7	$1\frac{1}{4}$
216	5.9	19.1	33.8	$1\frac{7}{16}$
218	5.8	15.1	29.8	$1\frac{1}{2}$
216	5.75	9.8	24.5	$1\frac{11}{16}$
216	5.7	5.0	19.7	$1\frac{7}{8}$
227	6.1	0	14.7	$2\frac{1}{16}$

TEST B

Time of arc approximately three seconds.

Voltage in circuit	Current amperes	Pressure gage lb./sq. in.	Pressure absolute lb./sq. in.	Length of arc. inches
220	3.5	0	14.7	1 1/4
218	3.45	5.4	20.1	1 1/8
212	3.4	10.4	25.1	1 1/16
208	3.35	15.3	30.0	1
224	3.5	20.7	35.4	15/16
225	3.6	25.5	40.2	7/8
218	3.4	31.6	46.3	3/4
220	3.5	36.8	51.5	11/16
222	3.5	31.0	45.7	3/4
220	3.5	25.4	40.1	7/8
224	3.55	20.0	34.7	1
223	3.5	14.4	29.1	1 1/8
224	3.55	9.3	24.0	1 1/16
222	3.4	5.0	19.7	1 1/4
222	3.5	0	14.7	1 1/4

TEST C

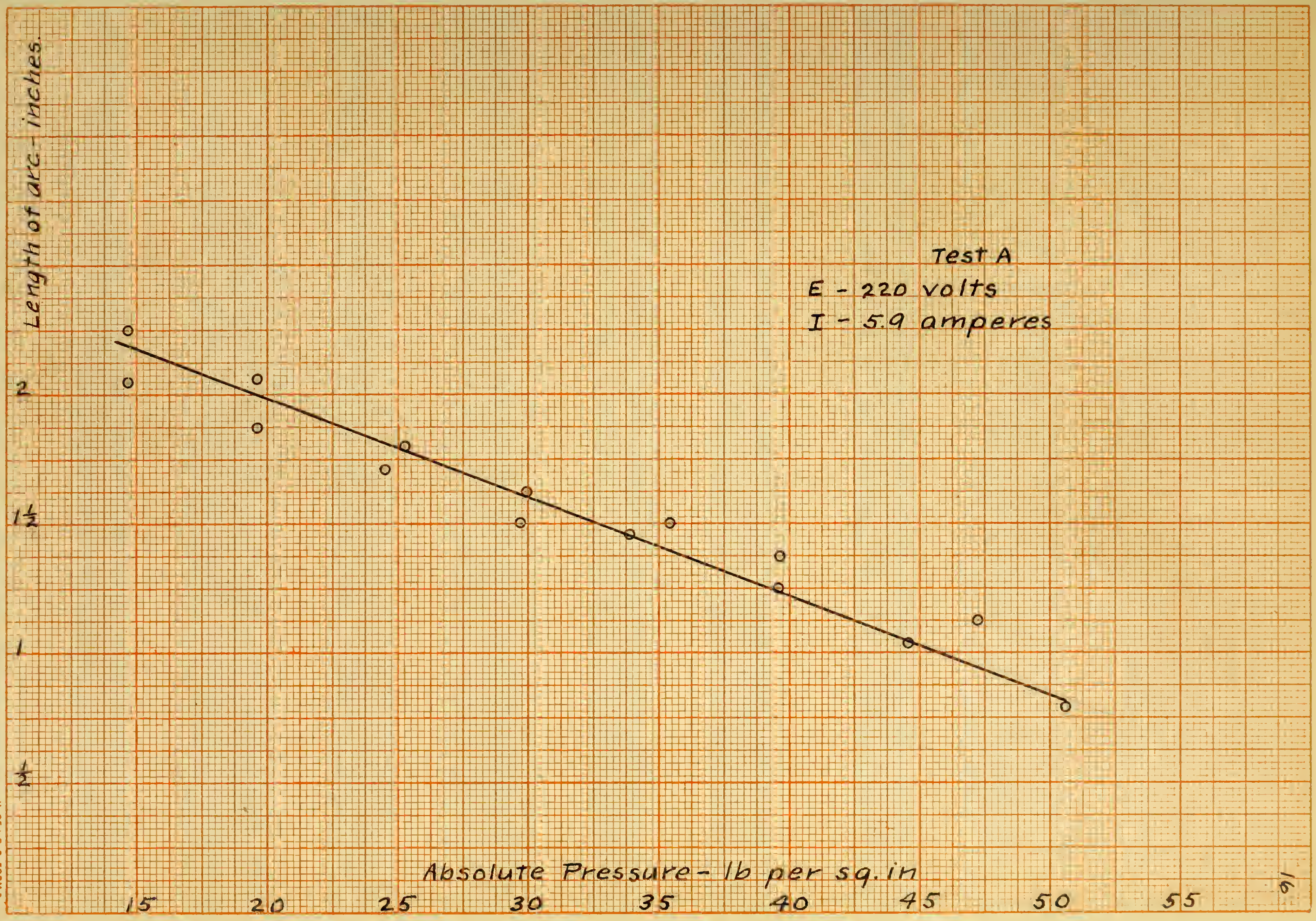
Time of arc approximately three seconds.

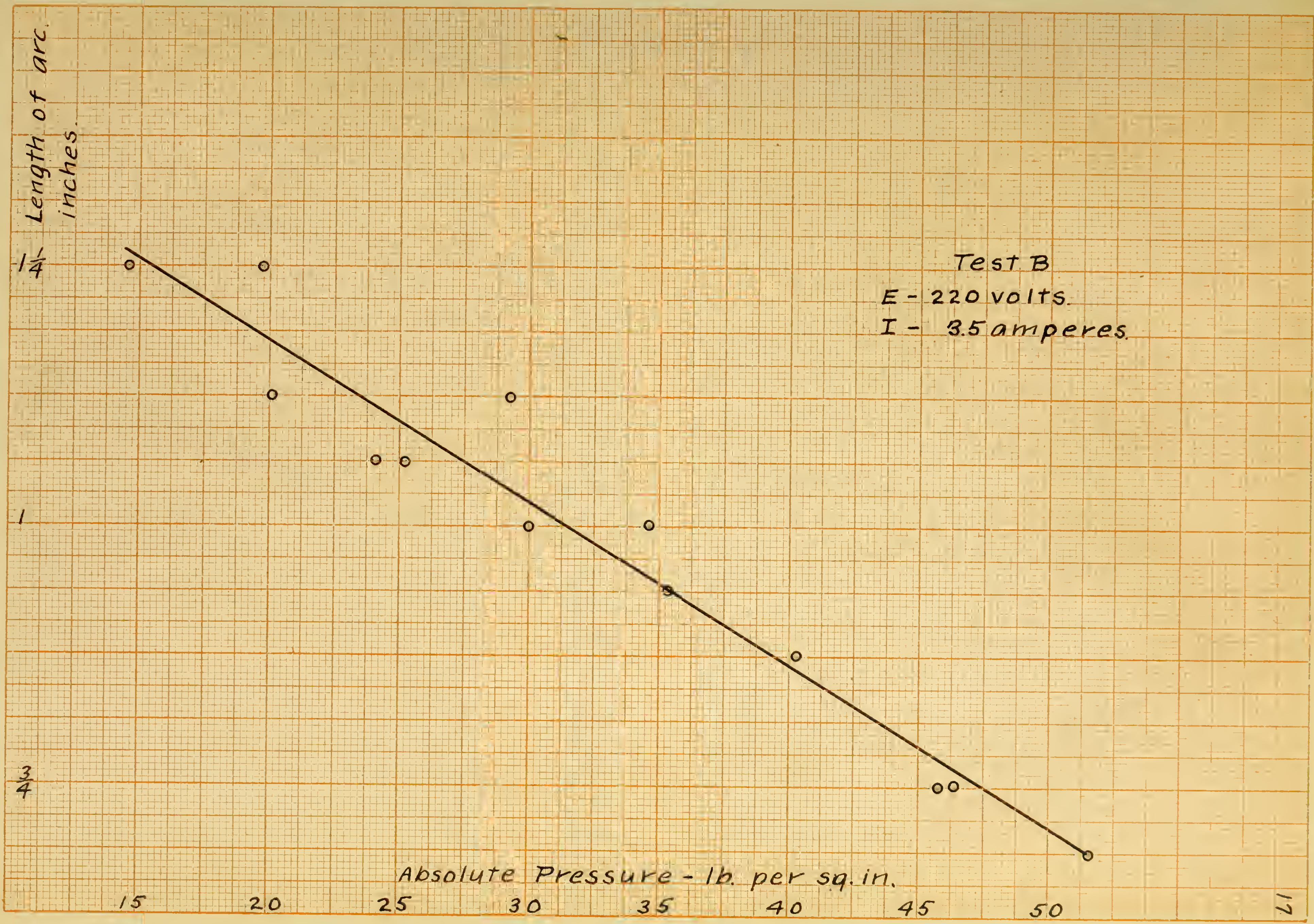
Voltage in circuit	Current amperes	Pressure gage lb./sq.in.	Pressure absolute lb./sq.in	Length of arc. inches.
525	1.1	0	14.7	$1\frac{1}{4}$
525	1.15	5.0	19.7	$1\frac{1}{4}$
530	1.15	10.0	24.7	$1\frac{3}{16}$
530	1.15	16.0	30.7	$1\frac{3}{32}$
465	1.0	20.5	35.2	$\frac{3}{4}$
460	1.0	24.0	38.7	$\frac{5}{8}$
450	1.0	29.0	43.7	$\frac{5}{8}$
455	.95	36.2	50.9	$\frac{1}{2}$
450	1.0	30.0	44.7	$\frac{5}{8}$
445	.95	24.0	38.7	$\frac{11}{16}$
440	.95	19.5	34.2	$\frac{3}{4}$
445	.95	15.0	29.7	$\frac{7}{8}$
455	.95	10.5	25.2	$\frac{7}{8}$
455	1.0	5.0	19.7	1
455	1.0	0	14.7	1

TEST D

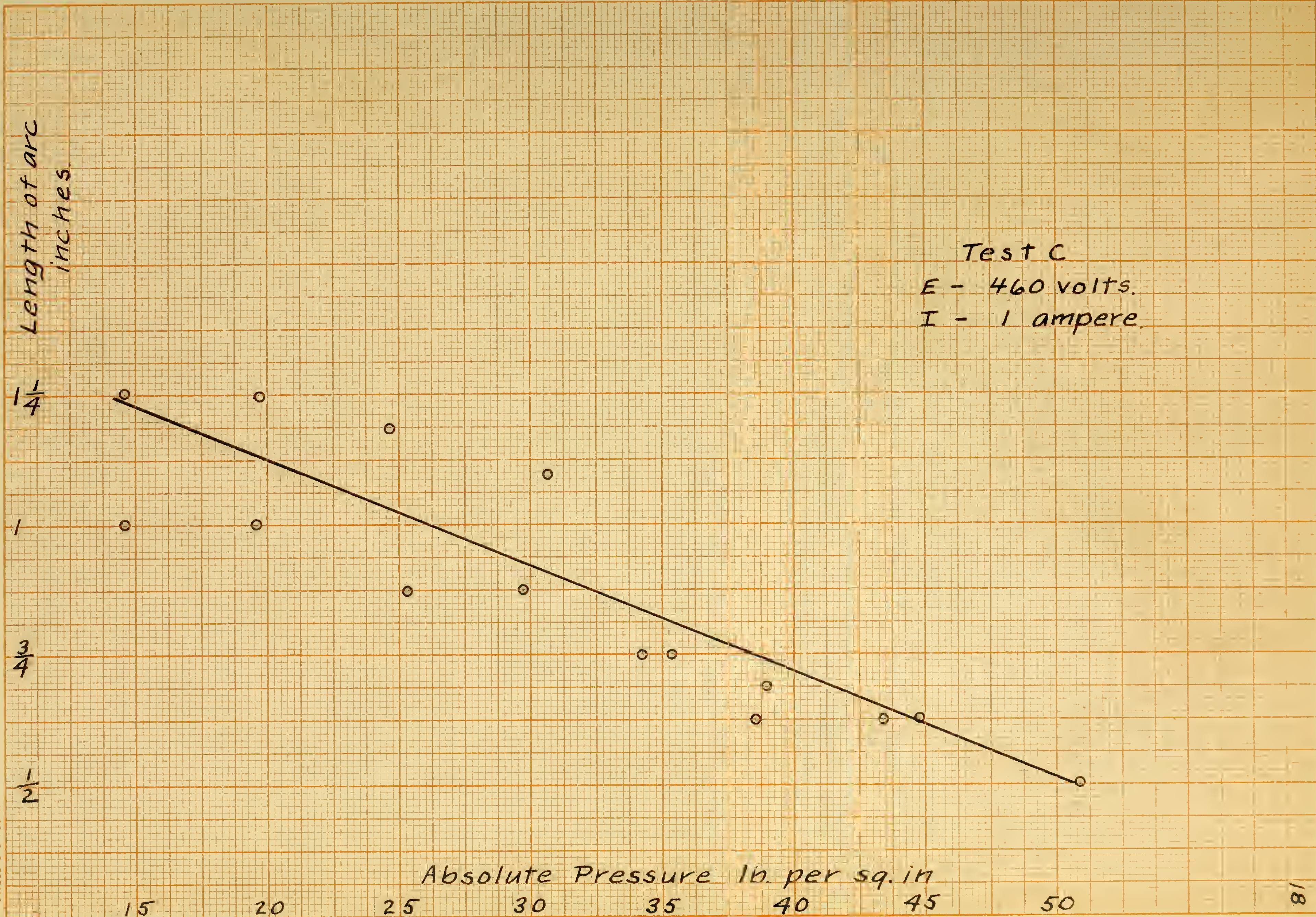
Time of arc approximately three seconds

Voltage in circuit.	Current amperes	Pressure gage lb./sq.in.	Pressure absolute lb./sq.in.	Length of arc. inches.
113	2.92	0	14.7	11/16
113	2.9	5.0	19.7	9/16
112	2.89	9.8	24.5	17/32
113	2.87	16.0	30.7	1/2
112	2.85	22.0	36.7	15/32
113	2.88	27.0	41.7	7/16
113	2.88	29.0	43.7	13/32
114	2.87	23.5	38.2	1/2
109	2.75	17.3	32.0	17/32
109	2.77	9.0	23.7	9/16
109	2.73	5.0	19.7	19/32
108	2.75	0	14.7	19/32

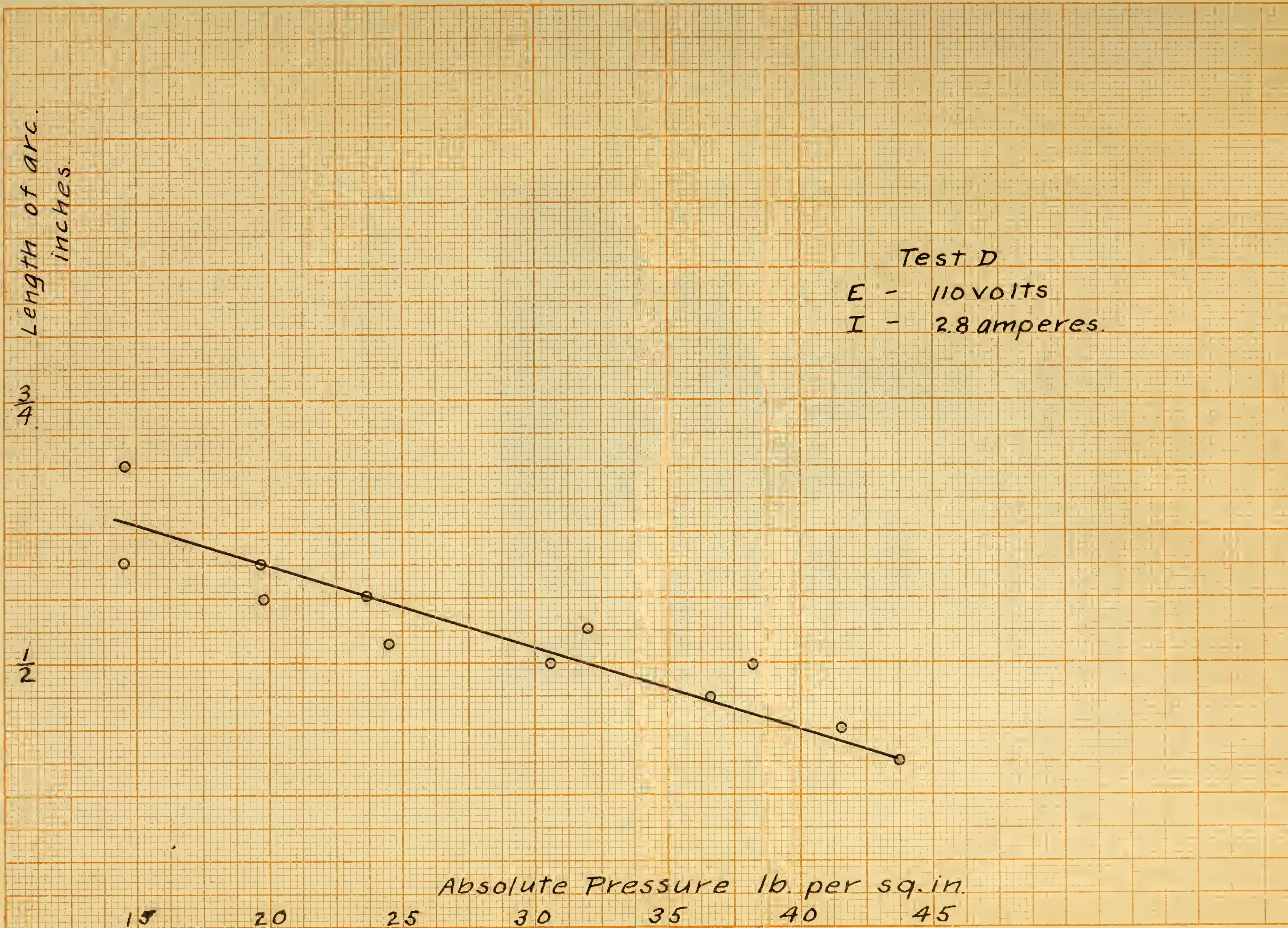

Test A
E - 220 volts
I - 5.9 amperes
Length of arc - inches.
Absolute Pressure - lb per sq. in
2
1½
1
½
15
20
25
30
35
40
45
50
55
16
U. OF I. S. S. FORM 3

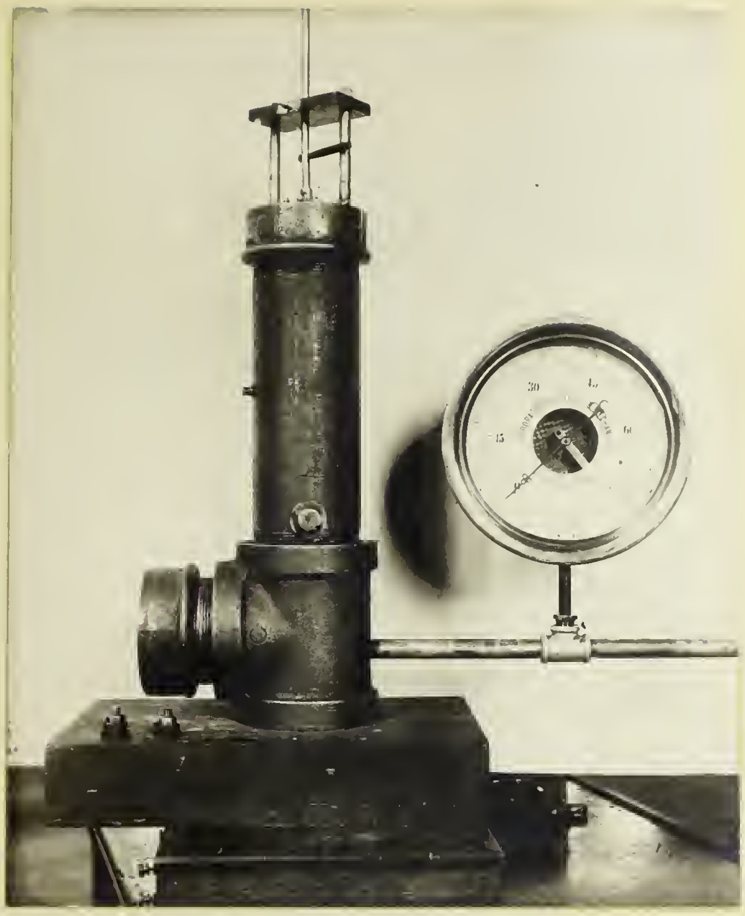


Length of arc. inches.
Test B
E - 220 volts.
I - 3.5 amperes.
$1\frac{1}{4}$
1
$\frac{3}{4}$
Absolute Pressure - lb. per sq. in.
15
20
25
30
35
40
45
50
17

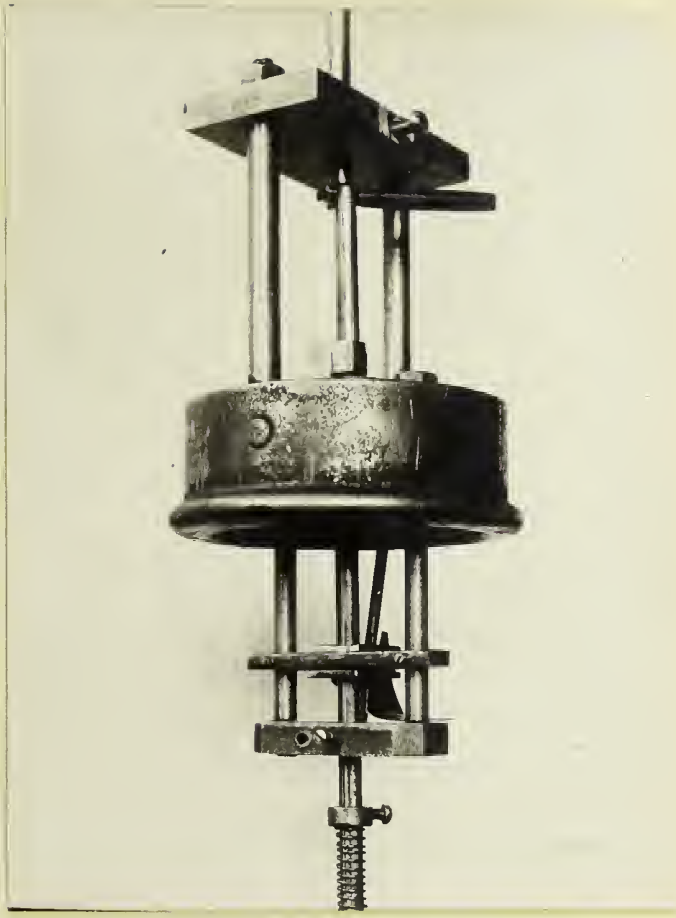


U. CF. I. S. S. FORM 3

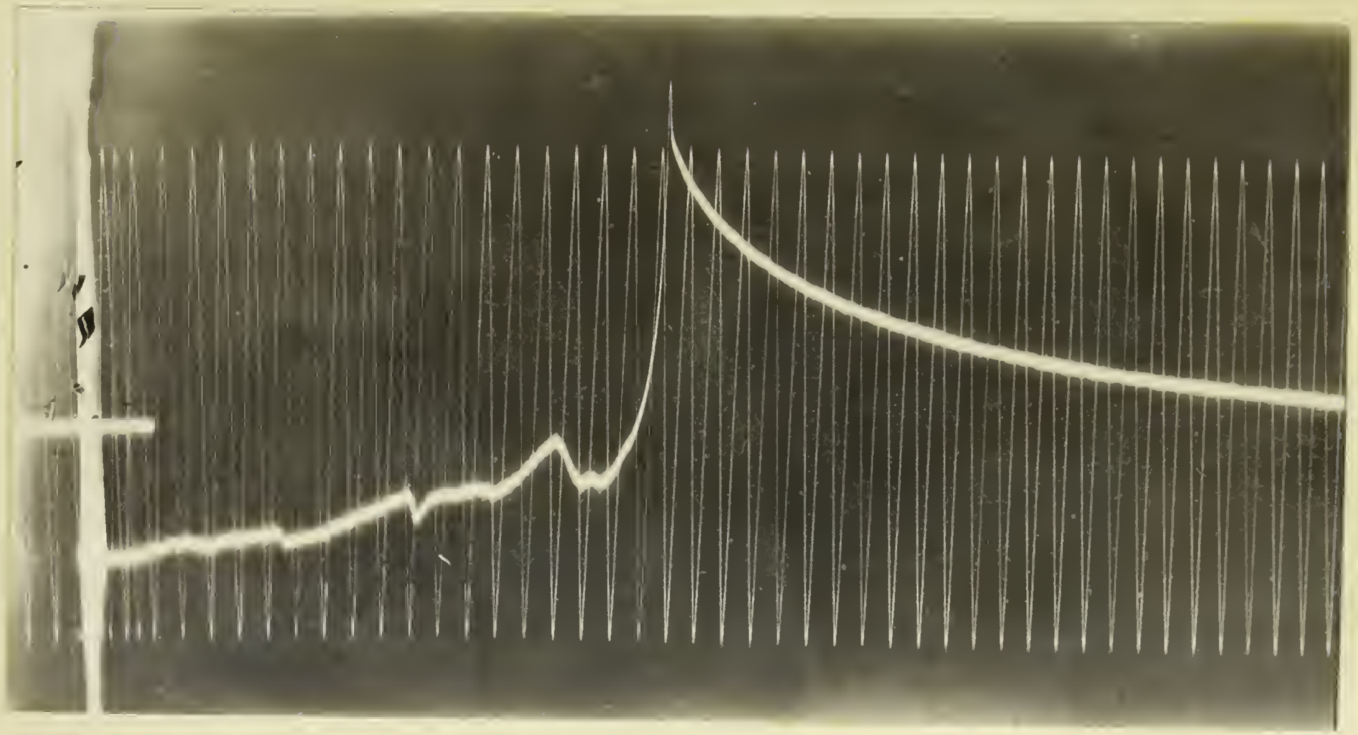

Length of arc.
inches.
3/4
1/2
Test D
E - 110 volts
I - 2.8 amperes.
Absolute Pressure lb. per sq. in.
15
20
25
30
35
40
45



COMPRESSED AIR SWITCH



TOP CAP AND TRIPPING MECHANISM



Oscillogram of Rise of Voltage across Switch on breaking 5.9 amperes Direct Current at 213 volts. Time curve frequency 63.5 cycles.

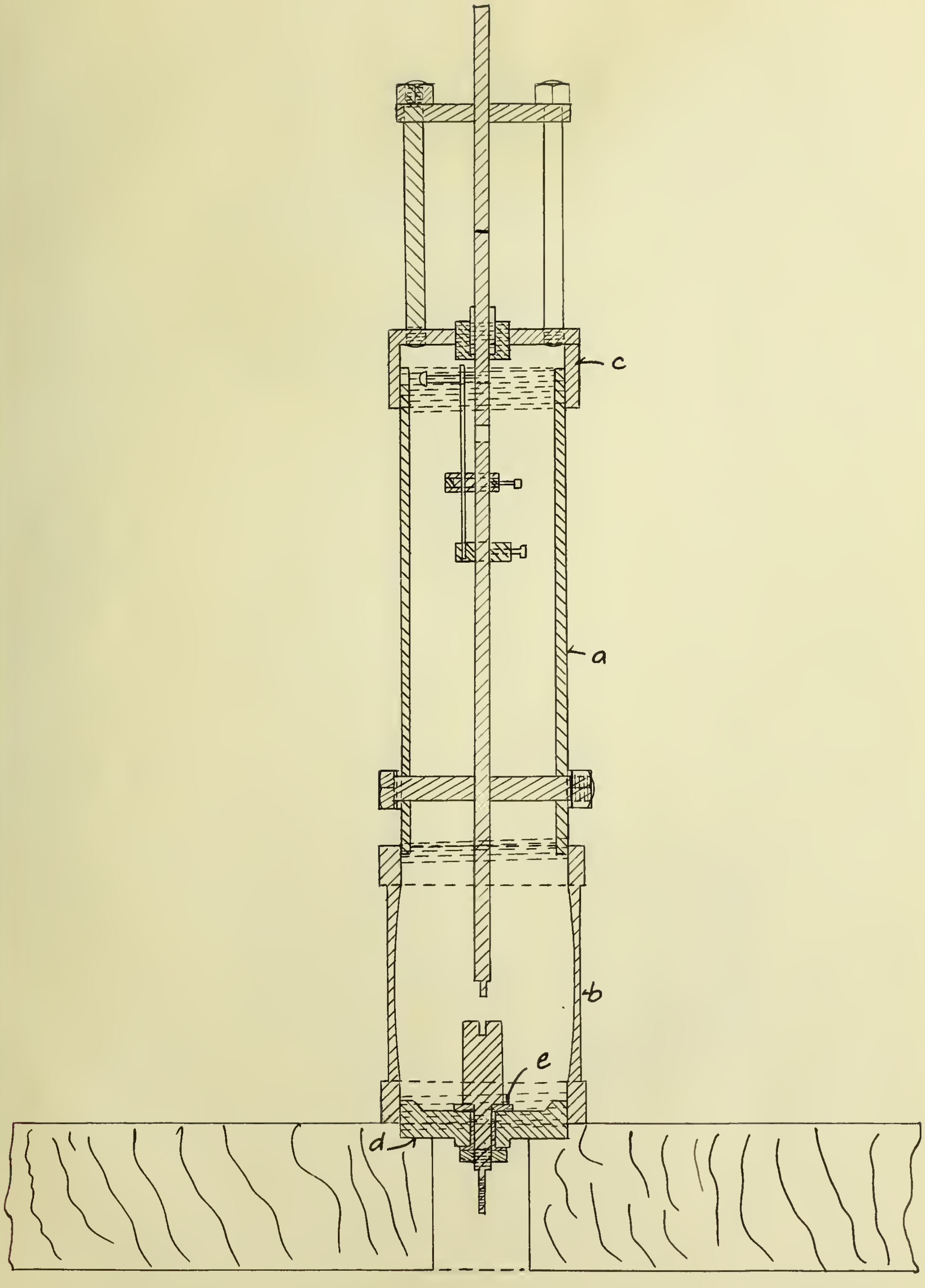
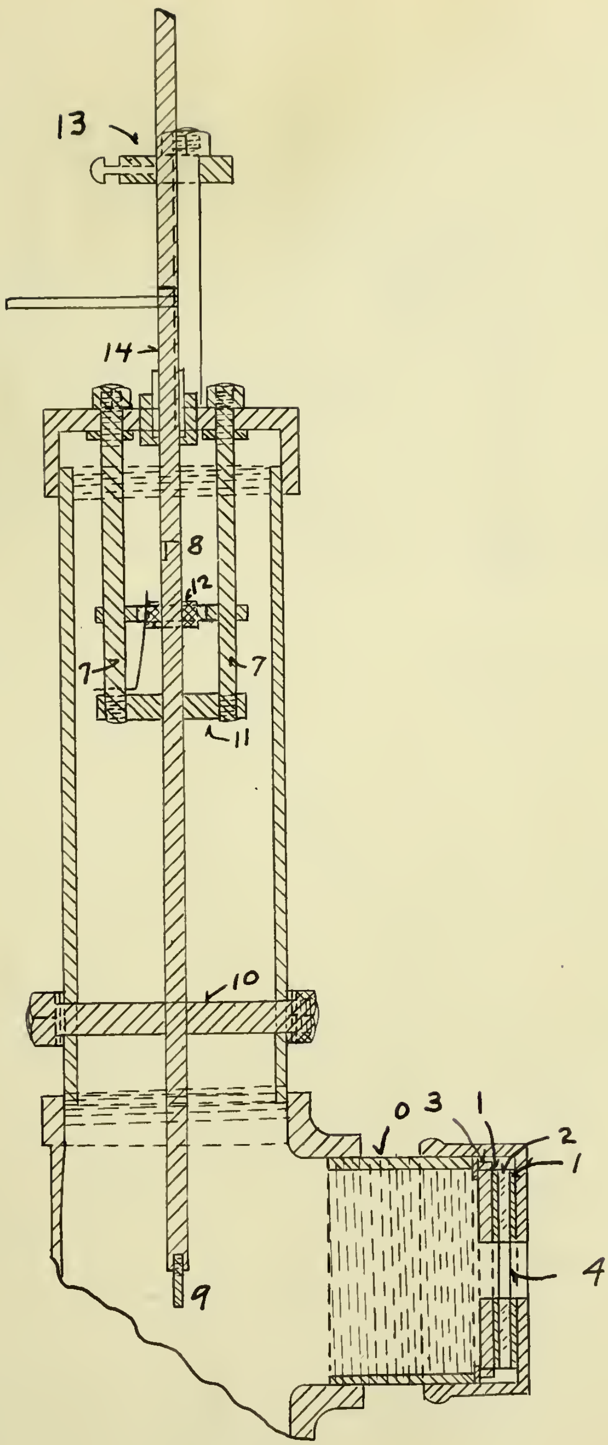


Plate I



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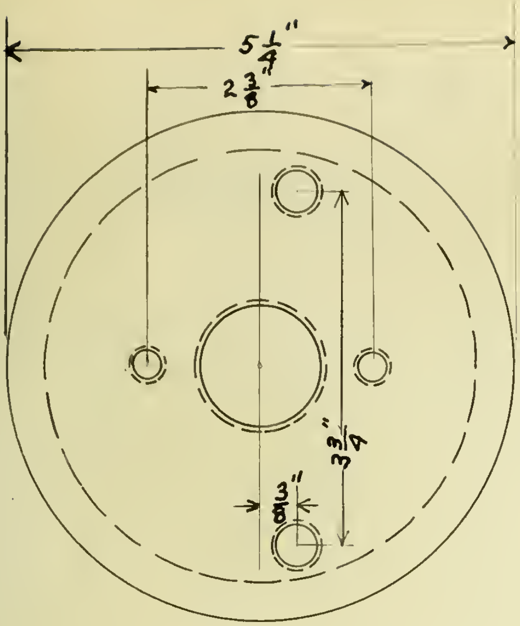

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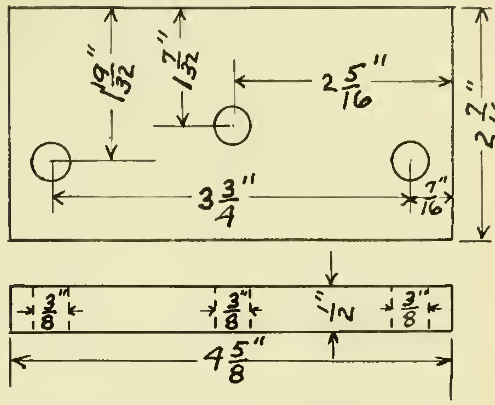

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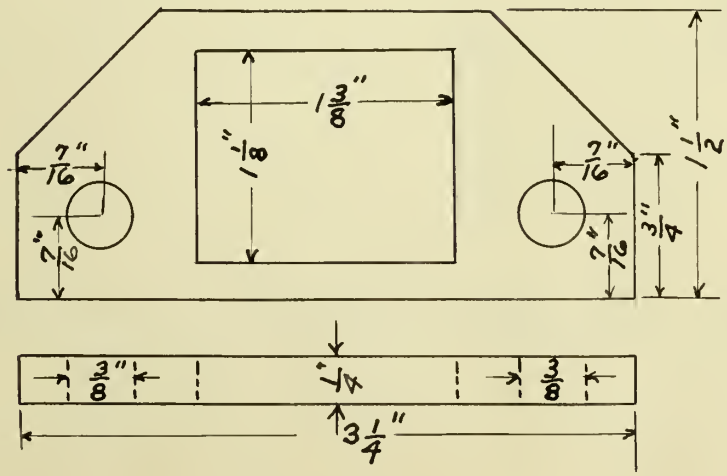

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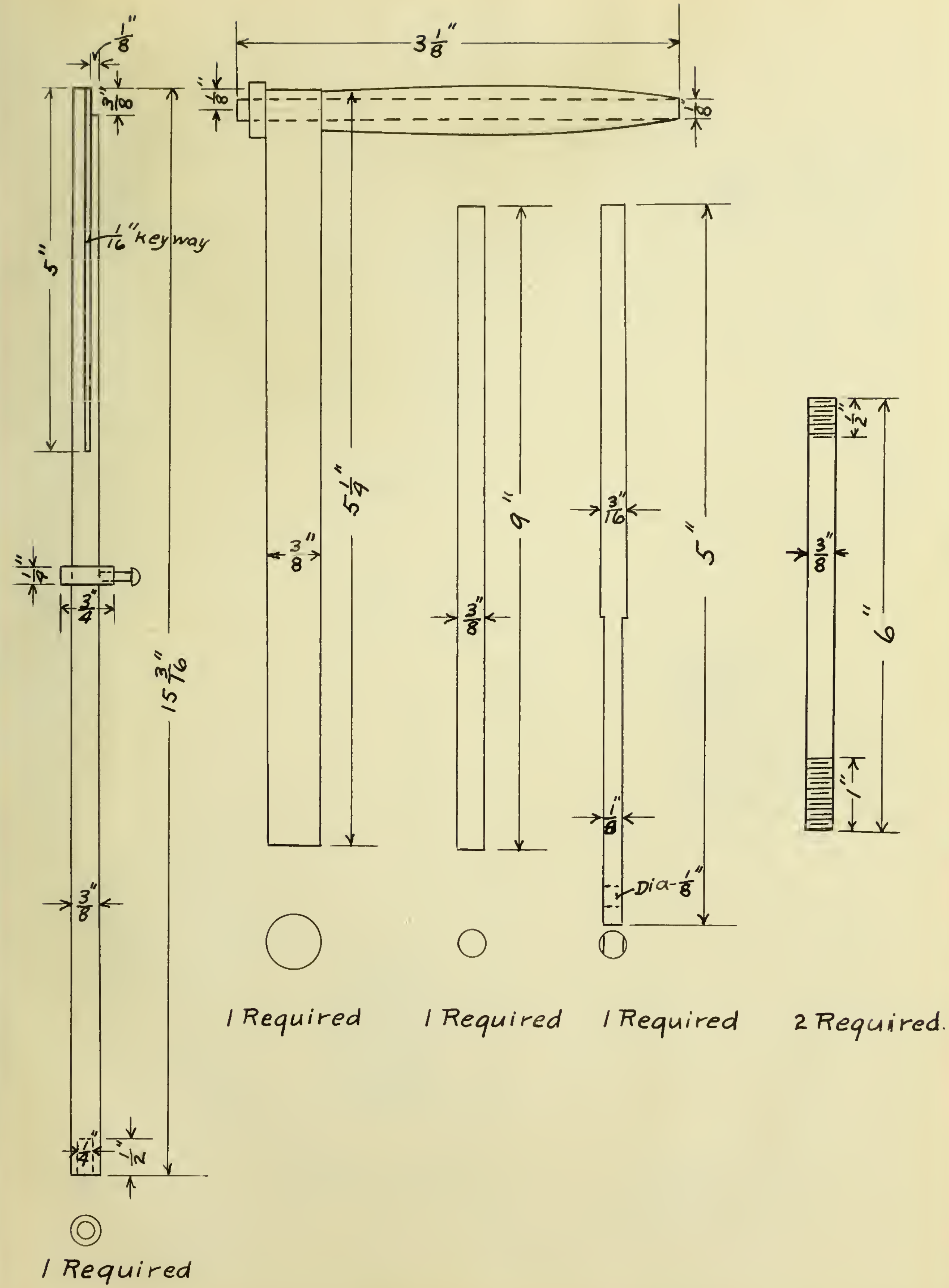
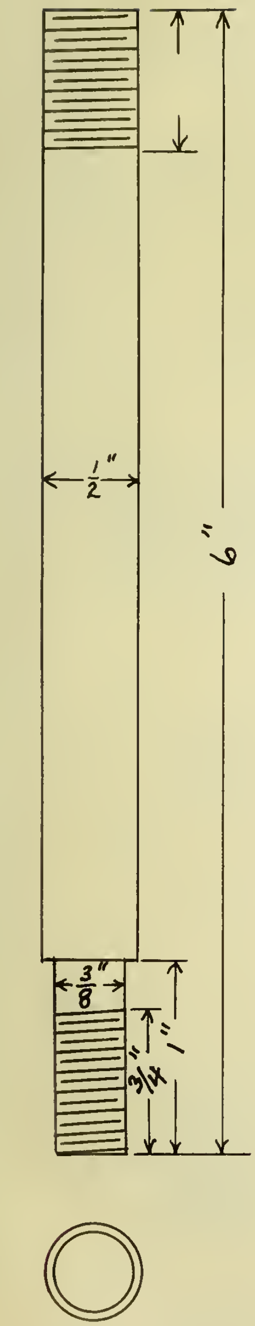

1/8"
3/16"
1/16" keyway
5"
1/4"
3/4"
15 3/16
3/8"
1/4"
1/2"
1 Required
3 1/8"
1/8"
5 1/4"
3/8"
1 Required
9"
3/8"
1 Required
3/16"
5"
1/8"
Dia-1/8"
1 Required
1/2"
3/8"
6"
1"
2 Required.



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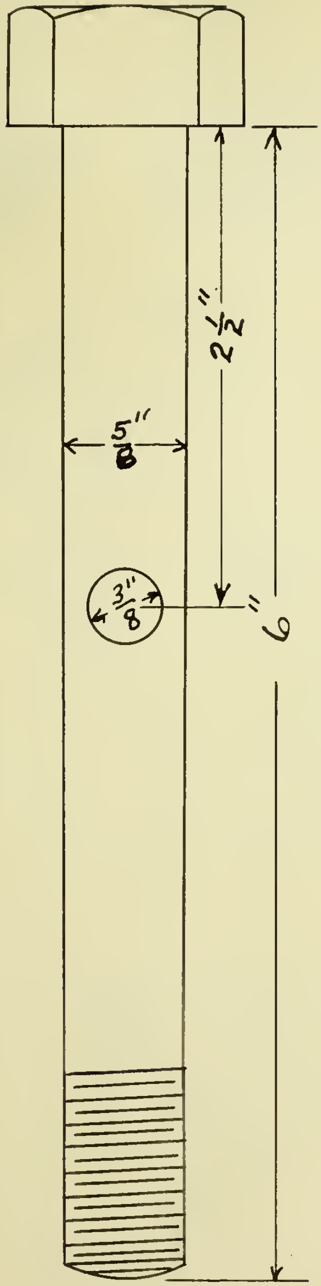

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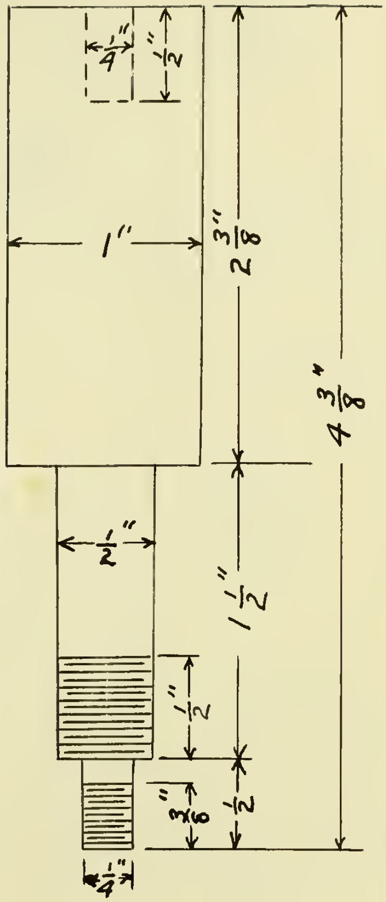

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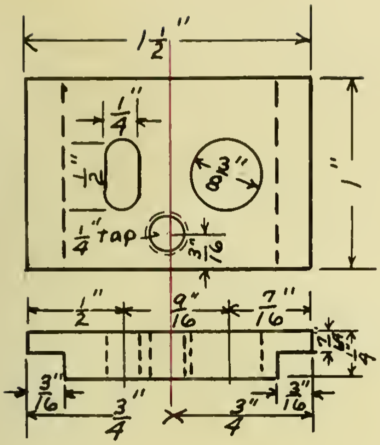
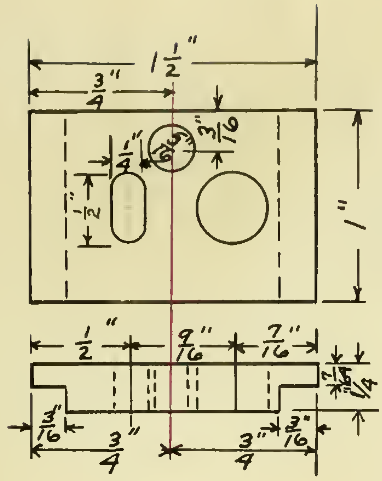
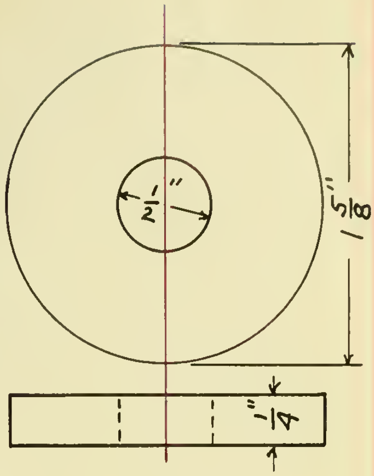
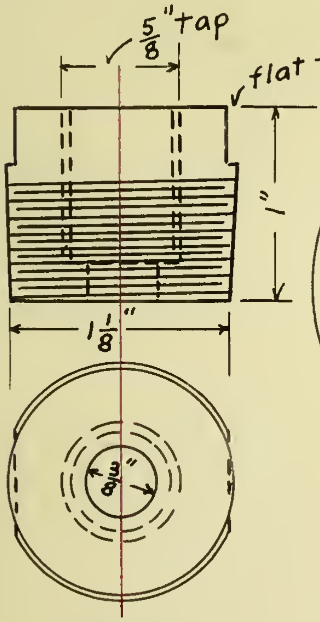
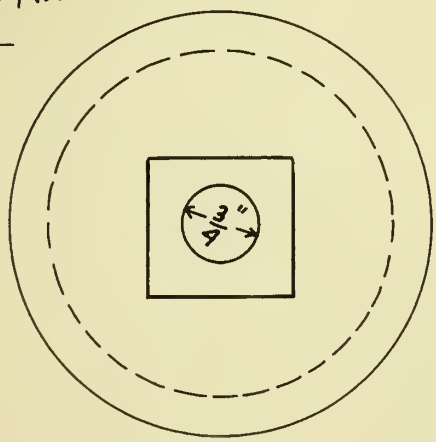


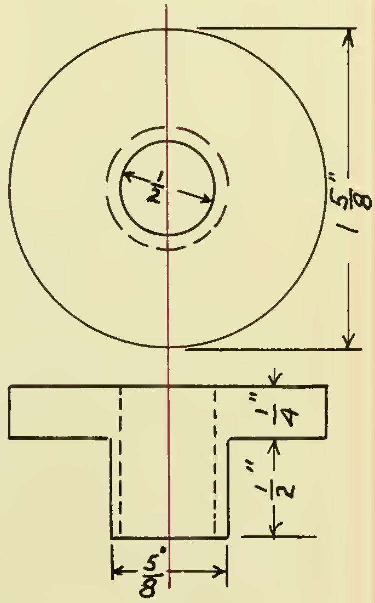


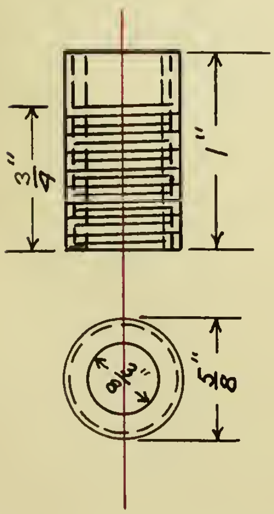


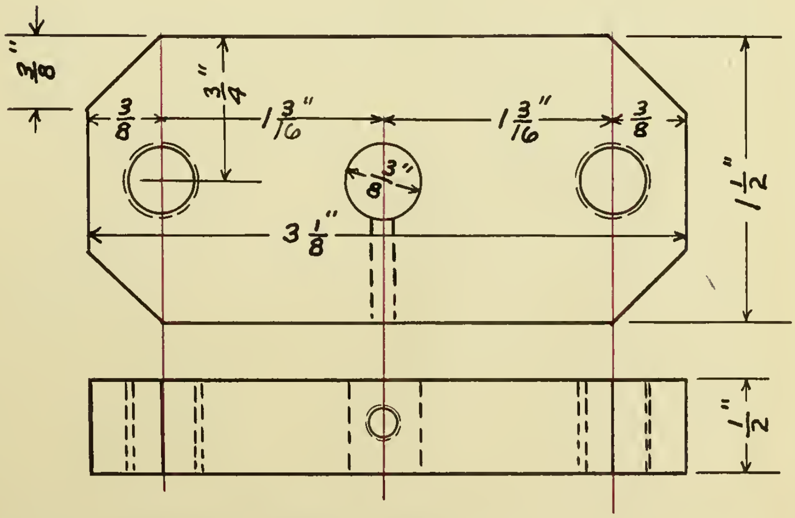




4 in. Pipe Plug







One of each required